Human Health Risks of Pathogens in Biosolids

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Outline

- How do we monitor for pathogens in wastewater, biosolids, and the environment?
- How are biosolids treated to reduce pathogen loads?
- What is known about pathogen exposure risks related to land application of biosolids?

The Pathogen(s) Problem…

CLASS	EXAMPLES	DISEASE
Bacteria	*Shigella sp.*	Bacillary dysentery
	Salmonella sp.	Salmonellosis (gastroenteritis)
	Salmonella typhi	Typhoid fever
	Vibrio cholerae	Cholera
	Enteropathogenic-Escherichia coli	A variety of gastroenteric diseases
	Yersinia sp.	Yersiniosos (gastroenteritis)
	Campylobacter jejuni	Campylobacteriosis (gastroenteritis)
Viruses	Hepatitis A	Infectious hepatitis
	Norwalk virus	Acute gastroenteritis
	Rotaviruses	Acute gastroenteritis
	Polioviruses	Poliomyelitis
	Coxsackie viruses	"flu-like" symptoms
	Echoviruses	"flu-like" symptoms
Protozoa	*Entamoeba histolytica*	Amebiasis (amoebic dysentery)
	Giardia lamblia	Giardiasis (gastroenteritis)
	Cryptosporidium sp.	Crytosporidiosis (gastroenteritis)
	Balantidium coli	Balantidiasis (gastroenteritis)
Helminths	*Ascaris sp.*	Ascariasis (roundworm infection)
	Taenia sp.	Taeniasis (tapeworm infection)
	Necator americanus	Ancylostomiasis (hookworm infection)
	Trichuris trichuria	Trichuriasis (whipworm infection)

Source: Smith, 2013. Historical review of US guidance and regulations for sludge disinfection and stabilization including a future projection. *27th Annual Residuals and Biosolids Conference.*

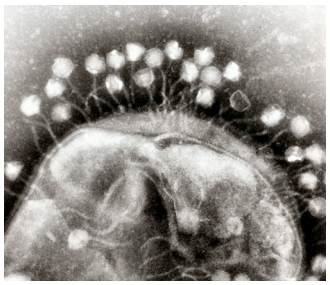
Indicator Organisms

- Nonpathogenic
  - Coliforms/*E. coli*
  - Enterococci

- Pathogenic
  - *Salmonella*
  - Phages, enteric viruses
  - *Giardia*, *Cryptosporidium,* helminths

Two pathogen reduction goals

1. Pathogen load



2. Vector Attraction

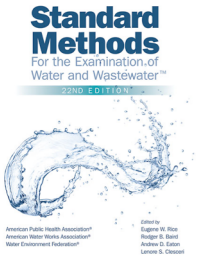
Federal rules

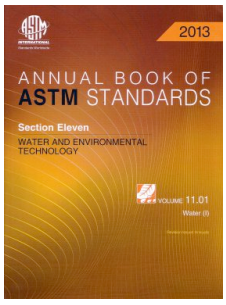
- 40 CFR 257 (1979):
  - Processes to Significantly Reduce Pathogens (PSRPs): 1 log reduction of pathogens
  - Processes to Further Reduce Pathogens (PFRPs): Complete reduction below analytical limits
- 40 CFR 503 (1993)
  - Vector Attraction Reduction (VAR) processes were separated
  - Division into Class A and Class B biosolids
  - Acceptable levels of pathogens and indicators were established

Methods for Pathogen Reduction

- Thermal
  - Composting
  - Pasteurization
- Drying
- Alkalinity
- Irradiation
- Unknown
- Innovative

40CFR503 Pathogen targets





- Class A:
  - Fecal Coliforms: < 10^3 CFU/g dw
  - Enteric Viruses: < 1 PFU/4 g dw
  - *Salmonella* spp.: < 3 MPN/4 g dw
  - Helmith ova: < 1 viable ova/4 g dw
- Class B:
  - Fecal Coliforms: < 2 x 10^6 CFU/g dw

Class B Use

- A variety of pathogens can persist
- Health risks are the result of complex interactions between factors
  - Pathogen concentration
  - Pathogen ecology
  - Geography/climate
  - Infectious dose
  - End use

TABLE 1

Class B contents

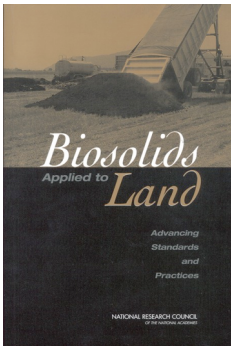
The following organisms are examples of pathogens found in Class B sewage sludge and associated symptoms of exposure. One or more species from the following groups of genera may be represented in Class B sludge.

Bacteria		Symptoms
Aeromonas	*Legionella*	Fever, chills, nausea, vomiting, severe abdominal pain, diarrhea, bloody stools, respiratory and sinus congestion, thick/colored mucus, rashes
Bacillus	*Listeria*	
Brucella	*Mycobacterium*	
Campylobacter	*Proteus*	
Citrobacter	*Pseudomonas*	
Clostridium	*Salmonella*	
Coxiella	*Shigella*	
Enterobacter	*Serratia*	
Erysipelothrix	*Staphylococcus*	
Escherichia	*Streptococcus*	
Francisella	*Yersinia*	
Klebsiella	*Vibrio*	
Viruses		
Astroviruses	Norwalk viruses	Fever, chills, nausea, vomiting, abdominal pain, diarrhea, severe headaches, congestion, respiratory distress, jaundice, paralysis, rashes
Caliciviruses	Reoviruses	
Hepatitis viruses	Rotaviruses	
Enteroviruses		
Protozoa		
Balantidium	*Giardia*	Intermittent diarrhea/constipation, abdominal pain/cramps, bloody stools, nausea, weight loss, dehydration
Cryptosporidium	*Toxoplasma*	
Entamoeba		
Helminth Worms		
Ascaris	*Taenia*	Fever, chest pain, bronchitis, diarrhea, vomiting, nutritional deficiencies, neurological problems, anorexia, weight loss, muscle aches
Hymenolepis	*Trichuris*	
Necator	*Toxocara*	

Source: U.S. EPA Office of Research and Development.

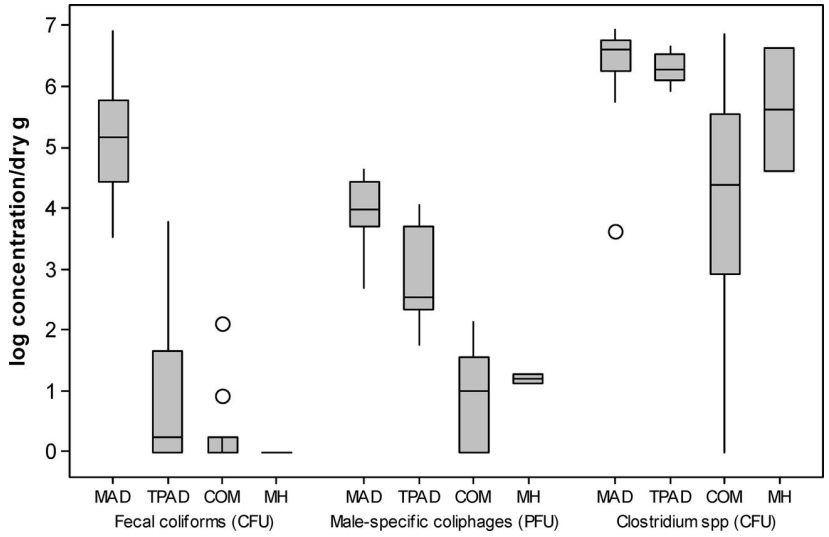
So What? Is it safe?

- "There is no documented scientific evidence that the Part 503 rule has failed to protect public health. However, …"
  - 2002 Report by NAS/NRC



- More recent review: pathogens occur in biosolids but risk is difficult to determine
  - Sidhu and Toze (2009) *Environment International* 35:187-201

Example of Available Data



Source: Viau and Peccia, 2009. *Appl Environ Microbiol 75:164-174*

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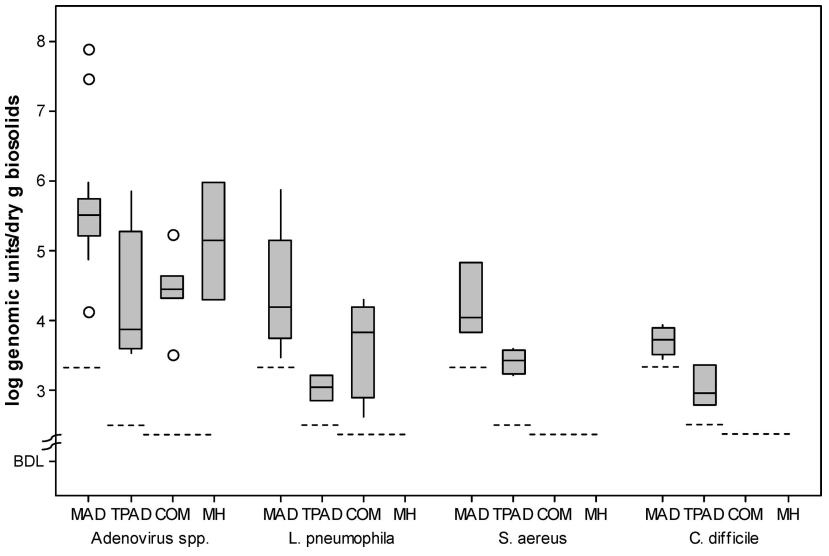


Source: Viau and Peccia, 2009. *Appl Environ Microbiol 75:164-174*

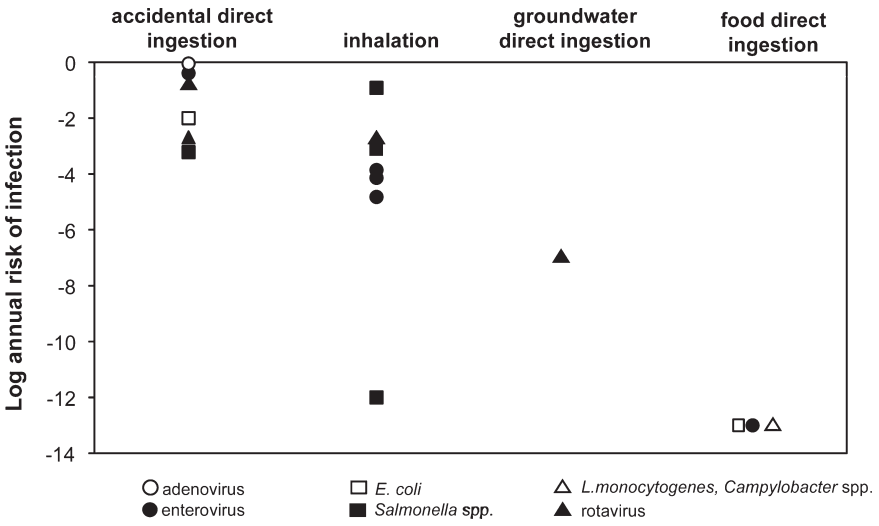
More Recent Research

- Pathogens generally low, except adenoviruses, but indicators generally high (1 log above limit) in nation-wide survey of class B solids
  - Pepper et al. (2010) *J Environ Qual* 39:2185-2190
- No regulated pathogens detected in soil 10 months after application
  - Zerzghi et al. (2010) *J Environ Qual* 39:402-408

Exposure and risks: epidemiology

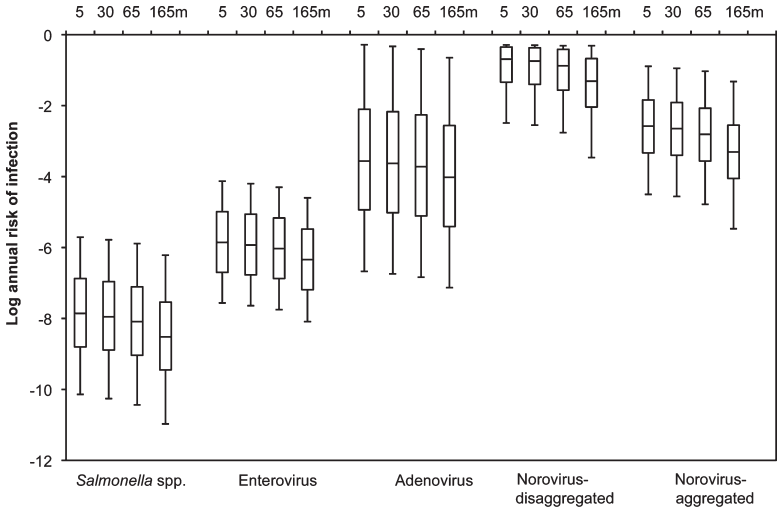
- Controlled epidemiological studies are the gold standard but little progress has been made in this area
- Two studies have conflicting results:
  - No difference found in one study although land application rates were below normal (Dorn et al. 1985. *Environ Res* 38:332-359)
  - A significant difference was found in another study that relied on self-reporting, which has many biases (Khuder et al. 2007. *Arch Environ Occup Health* 62:5-11)

Exposure and risks: modeling



Source: Viau et al., 2011. *Environ Sci Tech 45:5459-5469*

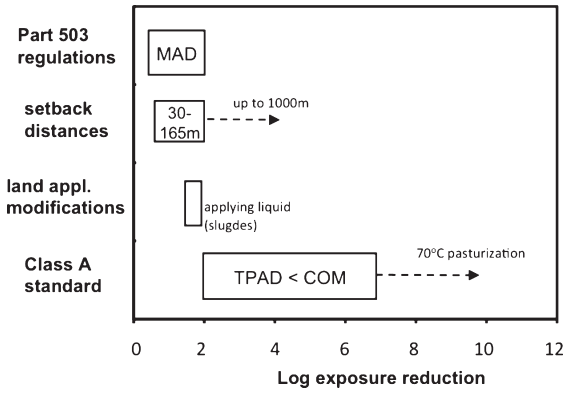
Exposure and risks: aerosols



Source: Viau et al., 2011. *Environ Sci Tech 45:5459-5469*

Reducing risk

- Improving sludge treatment processes is predicted to provide the greatest risk reductions by far



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Conclusions

- Monitoring for pathogens in sewage and the environment is a rapidly changing field
- Most current data suggests risks are low for most pathogen-exposure combinations except potentially inhalation of adeno- and norovirus
- Biosolid processing appears to be the most important factor in determining pathogen load and risk
- Need for more *and consistent* data on pathogens for proper risk assessment as use increases